Computational Science - ITB

Pengenalan Sains Komputasi - Spreading Fire

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Problem.

Develop a fire simulation in which every cell in a 17×17 grid has a tree and only the middle cell's tree is on fire initially. Do not consider the possibility of lightning or tree growth. The simulation should have a parameter for burnProbability, which is the probability of a tree adjacent to a burning tree catches fire. The function should return the percent of the forest burned. The program should run eight experiments with burnProbability = 10%, 20%, 30%,..., and 90% and should conduct each experiment 10 times. Also, have the code determine the average percent burned for each probability. Plot the data and fit a curve to the data. Discuss the results (Shodor, Fire).

Documentation.

Program dibuat sesuai kasus di atas tapi dengan memperhitungkan 8 arah/posisi grid untuk mengubah kondisi suatu grid, juga menggunakan *periodic boundary* sebagai batas grid. Program dibuat dalam bahasa C++ dan OpenGL untuk membuat animasinya.

Program

```
// Copyleft (c) Ridlo W. Wibowo
// Simple Spreading Fire
// Ref: Tharindra Galahena Code, game_of_life cellular automata
#include <iostream>
#include <cstdlib>
#include <ctime>
#include <iostream>
#include <stdlib.h>
```

```
#include <GL/gl.h>
#include <GL/glut.h>
#include <fstream>
#include <time.h>

#define MAX 17

using namespace std;

int grid [MAX][MAX];
int grid2[MAX][MAX];
bool f = false;
int tpm = 200;
double burnProb = 0.4;

double unirand(){ return (double)rand()/(double)RAND_MAX;}

void inisiasi();

void menu(int t){
  tpm = t;
  glutPostRedisplay();
}

void printm(){
    int m=0;
    ofstream out("fire.txt");
    for (int i=0;i<MAX;i++){
        for (int j=0;j<MAX;j++){
            if (grid[i][j] == 1){ m++;}
            out << grid[i][j] << " ";}
        out << "\n";}
    out.close();
    cout << "tree = " << m << endl;
    cout << "persentase = " << (double)m*100./((double)MAX*MAX) << endl;
}

int check(int i, int j){
    // with periodic boundary
    int s = 0;
  i += MAX;
  j += MAX;
    if (grid[i%MAX][j%MAX] == 1){
      if(grid[(i - 1)%MAX][(j - 1)%MAX] == 2 && unirand() < burnProb){ s++;}
      if(grid[(i - 1)%MAX][(j    )%MAX] == 2 && unirand() < burnProb){ s++;}
      if(grid[(i - 1)%MAX][(j + 1)%MAX] == 2 && unirand() < burnProb){ s++;}

      if(grid[(i    )%MAX][(j - 1)%MAX] == 2 && unirand() < burnProb){ s++;}
      if(grid[(i    )%MAX][(j + 1)%MAX] == 2 && unirand() < burnProb){ s++;}

      if(grid[(i + 1)%MAX][(j - 1)%MAX] == 2 && unirand() < burnProb){ s++;}
      if(grid[(i + 1)%MAX][(j    )%MAX] == 2 && unirand() < burnProb){ s++;}
      if(grid[(i + 1)%MAX][(j + 1)%MAX] == 2 && unirand() < burnProb){ s++;}

        return s;
  }
    else if (grid[i%MAX][j%MAX] == 2){return 999;}
    else{ return 888;}
}

void copy(){
  for(int i = 0; i < MAX; i++){
    for(int j = 0; j < MAX; j++){
      grid[i][j] = grid2[i][j];
    }
  }
}

void spread(){ // update
  for(int i = 0; i < MAX; i++){
    for(int j = 0; j < MAX; j++){
            int s = check(i, j);
            if (s == 0){ grid2[i][j] = 1;} // ada pohon dan gak kebakar
            if (s > 0 && s < 9){ grid2[i][j] = 2;} // pohon terbakar
            if (s == 999){ grid2[i][j] = 0;} // udah kebakar jadi empty
            if (s == 888){ grid2[i][j] = 0;} // tetep empty
    }
  }
  copy();
}

void par(float x1, float x2, float y1, float y2, int val){
  if (val == 0){glColor3f(1.0, 1.0, 1.0);}
    else if(val == 1){ glColor3f(0.0, 1.0, 0.0);}
    else{glColor3f(1.0, 0.0, 0.0);}

  glBegin(GL_QUADS);

  glVertex3f(x1, y1, 0.0);
  glVertex3f(x2, y1, 0.0);
  glVertex3f(x2, y2, 0.0);
  glVertex3f(x1, y2, 0.0);

  glEnd();
}

void display(void)
{
  glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
  glMatrixMode(GL_MODELVIEW);
  glLoadIdentity ();

  glTranslatef(0.0, 0.0, -22.0);

  for(int i = 0; i < MAX; i++){
    for(int j = 0; j < MAX; j++){
        par(-6.0 + 0.7 * j + 0.1,
          -6.0 + 0.7 * (j + 1),
          6.0 - 0.7 * i + 0.1,
          6.0 - 0.7 * (i - 1),
                    grid[i][j]);
    }
  }

  glutSwapBuffers();
}

void myIdleFunc(int a) {
  spread();
  glutPostRedisplay();
  if(f) glutTimerFunc(tpm, myIdleFunc, 0);
}

void inisiasi(){
  for (int i=0;i<MAX;i++){
        for (int j=0;j<MAX;j++){
            grid2[i][j] = 1;
        }
    }
    grid2[8][8] =  2;

    copy();
}

void keyboard(unsigned char key, int x, int y){
  if(key == 27) {
    exit(0);
  }else if((char)key == 'a'){
    if(!f) glutTimerFunc(tpm, myIdleFunc, 0);
    f = true;
  }else if((char)key == 's'){
    spread();
    glutPostRedisplay();
  }else if((char)key == 'd'){
    f = false;
  }else if((char)key == 'f'){
    inisiasi();
        f = false;
    glutPostRedisplay();
  }else if((char)key == 'p'){
        f = false;
        printm();
    }

```

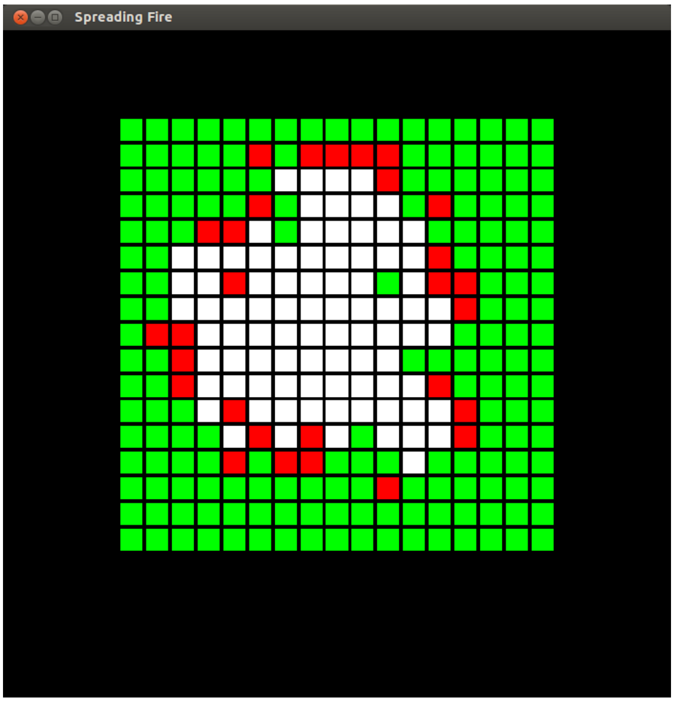
```
}

void init(){
  glEnable(GL_DEPTH_TEST);
  glEnable(GL_COLOR_MATERIAL);

  glEnable(GL_LIGHTING);
  glEnable(GL_LIGHT0);
  glEnable(GL_NORMALIZE);
  glShadeModel(GL_SMOOTH);
  glLoadIdentity ();
  glOrtho(-1.0, 1.0, -1.0, 1.0, -1.0, 1.0);

  GLfloat acolor[] = {1.4, 1.4, 1.4, 1.0};
  glLightModelfv(GL_LIGHT_MODEL_AMBIENT, acolor);
}

void Reshape(int w, int h){
    glViewport(0, 0, w, h);
    glMatrixMode(GL_PROJECTION);
  glLoadIdentity();
  gluPerspective(45.0, (float)w/(float)h, 0.1, 200.0);
}

int main(int argc, char** argv){
    cout << "Input burnProbablity : "; cin >> burnProb;
  srand(time(NULL));
    inisiasi();

  glutInit(&argc,argv);
  glutInitDisplayMode ( GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);
  glutInitWindowSize(700,700);
  glutInitWindowPosition(500,0);
  glutCreateWindow("Spreading Fire");
  glutCreateMenu(menu);

  glutAddMenuEntry( "20",  20);
  glutAddMenuEntry( "40",  40);
  glutAddMenuEntry( "60",  60);
  glutAddMenuEntry("100", 100);
  glutAddMenuEntry("150", 150);
  glutAddMenuEntry("200", 200);

  glutAttachMenu(GLUT_RIGHT_BUTTON);
  init();
  glutReshapeFunc(Reshape);
  glutKeyboardFunc(keyboard);
  glutDisplayFunc(display);

  glutMainLoop();
  return 0;
}
```

Setelah program dijalankan dapat dilakukan beberapa hal:

- input burnProb, input dari terminal (kemudian layar simulasi muncul)
- tombol a = run simulasi otomatis
- tombol s = run simulasi per step
- tombol d = pause simulasi
- tombol f = restart simulasi
- tombol p = print kondisi (persen terbakar dan file berisi matriksnya)
- tombol ESC = stop, exit
- klik kanan pada layar simulasi, lalu pilih kecepatan simulasi (untuk kasus tombol a)

belum terbakar, sedang terbakar, dan sudah terbakar ditunjukkan dengan warna hijau, merah, dan putih. Contoh animasi dapat dilihat di `http://astrokode.wordpress.com/2012/11/28/spreading-fire-simulation-v01-with-opengl/`.

Screenshot:



Screenshot layar simulasi.

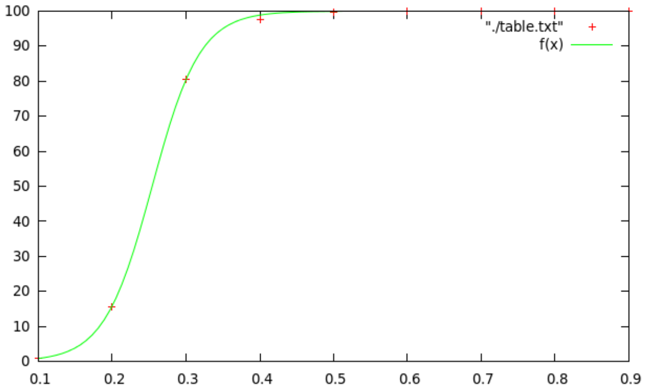
Hasil run untuk beberapa *burnProbablity*:

burnProb	average % burned after 10× run
0.1	1.007
0.2	15.743
0.3	80.657
0.4	97.647
0.5	99.723
0.6	99.931
0.7	100.0
0.8	100.0
0.9	100.0

Dengan melihat angka pada tabel di atas lalu dilakukan fitting menggunakan fungsi logistik sebagai berikut:

$$f(x) = \frac{100}{1 + Ae^{-\lambda x}} \tag{0.1}$$

menggunakan fitting nonlinear pada *gnuplot* diperoleh:
(sebenarnya bisa diubah menjadi fitting linear karena nilai maksimum sudah diketahui – 100%)
$A = 2532.45 \pm 320.7$
$\lambda = 30.8436 \pm 0.482$



Plot data (+ merah) dan fitting menggunakan fungsi logistik (garis hijau).

Diskusi

1. Terjadi lonjakan nilai persentase terbakar untuk *burnProb* antara 0.2 dan 0.3, ketika nilainya lebih besar dari itu, hampir semua grid pasti terbakar habis, jika kurang dari itu api susah menyebar (terdapat nilai kritis).
2. Bentuk fungsi logistik cocok untuk menggambarkan peristiwa ini.